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FOOD PRESERVATION BY LOW DOSE GAMMA IRRADIATION

By R.F. ERRINGTON, M.A.
Manager
Commercial Products Division.
Atomic Energy of Canada Limited
Ottawa, Canada

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FOOD PRESERVATION BY LOW DOSE GAMMA IRRADIATION

by
R. F. Errington, B.A., Manager
Commercial Product Division
Atomic Energy of Canada Limited
Ottawa, Canada

1. (a) Food preservation by gamma irradiation appears to have promise as a method of increasing food supplies in areas of the world where shortages exist and where climate and storage conditions contribute to excessive spoilage. It should also be valuable in extending shelf life of fresh products to permit marketing over a longer period and at greater distance from the production area.

(b) The amount of experimental work and the number of groups carrying on tests have increased substantially over the past some years. In our own case, and perhaps also in the case of others in the field, there has been a definite tendency to concentrate on specific products. This indicates that we feel that certain applications are closer to commercial realization than others.

(c) The Canadian program envisages three stages of accomplishment: initial scientific tests on small quantities, combined with observation of side effects; pilot plant tests at production or processing locations; and full scale processing on a commercial basis. Not all products under consideration will go through these stages at the same time.

(d) During the program of tests, information is accumulated from our own work and from the published works of others. This is used to prepare a submission to the Canadian Food and Drug Directorate by way of a recommendation that particular products be sold for human consumption. Up to now we have submitted only two such proposals covering potatoes and onions.

(e) The objective of food preservation by gamma radiation is, of course, to conserve the quantity or quality of the product. This method of conservation must be related to other ways of accomplishing a similar result and to the economics of the process. The factors to be considered within the above general objective will vary widely from one country to another and between areas in the same country.

(f) The dosage of gamma radiation required to accomplish food preservation depends upon the product and the type of change which should be produced. It varies over a broad range, from simple sprout inhibition of potatoes or onions at a few thousand rads to pasteurization or sterilization at dosages up to millions of rads. This presentation will consider only products which can be treated at the pasteurization level of dosage or lower.

(g) Based on the work done in Canada and elsewhere, a number of agricultural products appear amenable to treatment with gamma radiation.

(i) Commercial sprout inhibition of potatoes, onions, carrots, and garlic appears promising. Dose requirements are low at about 8,000 rads.

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(ii) The treatment of pork with doses of 20,000 to 30,000 rads removes the hazard of trichinosis. Technical feasibility has been established and commercial application may be imminent.

(iii) Doses of 20,000 to 50,000 rads will prevent reproduction of insects in stored cereal crops. Such treatment, combined with good storage conditions, should reduce the serious losses of food products which may occur, particularly in warm and tropical countries.

(iv) Radiation at the pasteurization level also holds much promise. The control of molds in strawberries and citrus fruits, brown rot in peaches, and delay in ripening of bananas, are examples of promising applications. Our experiments indicate that a dose of 85,000 rads will reduce the incidence of coreflush and scald in apples, and a dose of 200,000 rads extends the fresh shelf life of strawberries by several weeks when stored at 40°F following treatment. Dose levels from 100,000 to 600,000 rads have been used to extend the refrigerated shelf life of sea foods, such as cod, haddock, crabmeat, oysters, and shrimp. A program to study the preservation of scallops by radiation treatment is currently underway in Canada.

(v) Early commercial application of radiation treatment of poultry and egg products is anticipated. Salmonella organisms in frozen eggs can be destroyed at dosages of 300,000 to 500,000 rads.

2. (a) The time allocated to this paper precludes detailed examination of the work done on all products. I have therefore chosen to examine a specific case, namely, inhibition of sprouting of fresh vegetables and particularly potatoes. Over a period of years, many investigators have irradiated laboratory quantities of potatoes and observed the very favourable control of sprouting. The background for field tests, therefore, had been well prepared.

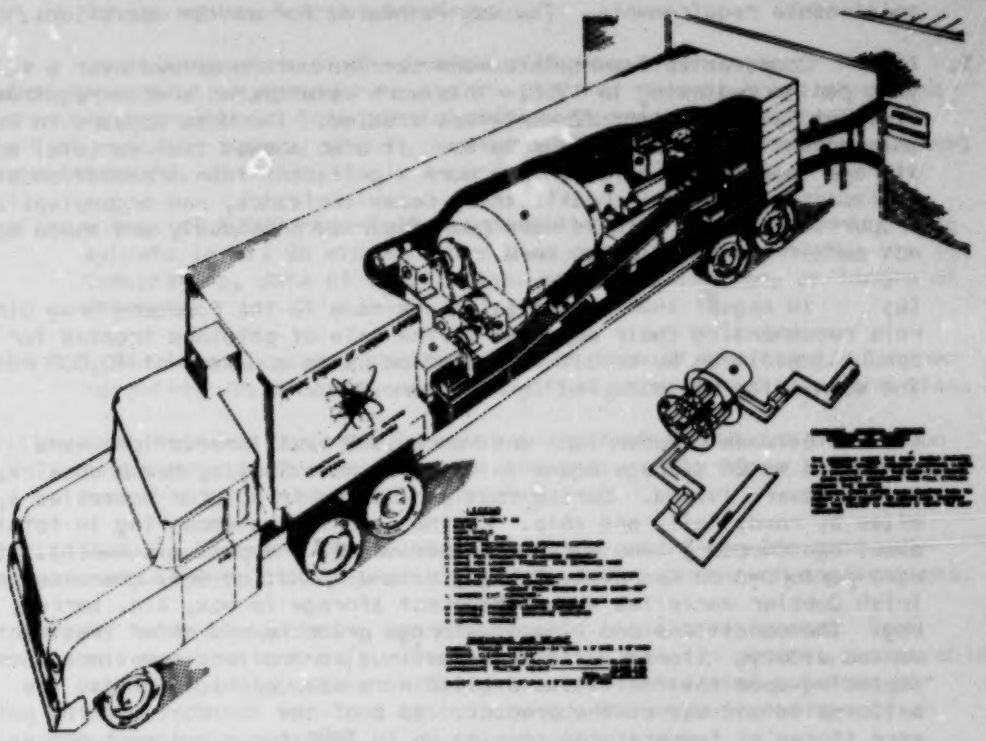
(b) In 1961 we designed and produced a Mobile Demonstration Irradiator. Massive tests of pilot plant quantities were performed in the fall of 1961 and again in 1962. It was and is our opinion that this work had to be taken closer to the producer, warehouse operator and processor so that the results could be observed locally on quantity lots. The MDI was not intended to operate at a volume which would permit satisfactory economics. Weight limitations made it necessary to use lead as a shielding material, thus increasing costs of fabrication compared with the use of concrete if a fixed irradiator had been used. In addition, we wished to use the MDI for experimental work on a variety of products. Consequently its design was considerably more complicated than would otherwise be necessary.

(c) The irradiator is mounted on a standard trailer 8' x 12' x 34' capable of highway transport. Details are as follows:

Source - Cobalt-60 sealed in double walled, double welded stainless steel capsules.

Shielding Capacity - 25,000 curies.

Shielding Material - 10" of lead in steel.



Mobile Demonstration Irradiator

Weight - Machine 65,000 lbs.
- Trailer 15,000 lbs.
- Tractor 12,000 lbs.

Throughput at 15,000 curies - 2,500 lbs. per hr. to a dose of 7,500 rads.

Dose Uniformity - ±15%.

Bucket Size - 8" x 8" x 15".

Exposure Time - Variable (3 minutes total for potatoes).

The type of construction is shown in Figure 1.

(d) As shown in the illustration, buckets are received on a conveyor, pass through the irradiation chamber, and are discharged on a separate conveyor at the same end of the van. Eight bucket positions are provided within the irradiation chamber, four each on two ferris wheel mountings. Each bucket therefore makes two complete revolutions around the rod style source, remaining upright at all times. This arrangement provides for relatively uniform dosage to all produce in the bucket. Control of the operation is accomplished simply from the console at the rear.

(e) The irradiator operated well in all types of weather, with minimum maintenance requirements. The van is heated for winter operations.

3. (a) Cooperative experiments were carried out in Ottawa over a three year period beginning in 1956. This work established a dose requirement of about 7,000 rads for 12 varieties studied. The dose appears to be independent of storage temperatures. It also showed that varietal and storage temperature effects were more significant than irradiation effects on important chemical constituents, decay incidence, and organoleptic properties. These results have been reported previously and space does not permit their inclusion here.

(b) In August 1960 a submission was made to the Food and Drug Directorate recommending their approval of the sale of potatoes treated for sprout inhibition by cobalt-60 radiation up to a dosage of 10,000 rads. The submission was accepted in November 1960.

(c) Between October 1961 and March 1962 test irradiations were performed at 26 storage areas in Ontario, Nova Scotia, New Brunswick, and Prince Edward Island. During this period the irradiator travelled 4,000 miles by road, rail, and ship. Further quantities amounting in total to about one thousand tons were processed during the past six months. Tests were performed on Kennebec, Sebago, Katahdin, Netted Gem, Cherokee, and Irish Cobbler varieties with subsequent storage in box, bin, barrel, and bag. The conditions and time of storage prior to and after treatment varied widely. Storage used was sometimes controlled, sometimes common, depending upon the facilities available to each participant and the anticipated end use of the product. In 8 of the 26 locations the potatoes were stored at temperatures ranging up to 70°F for subsequent processing. Potatoes in the other 18 locations were maintained in unheated storage for table stock use. The table below illustrates that irradiation is a completely effective sprout inhibitor even at high temperature storage.

Sprouting in Kennebec potatoes

		Sprouting			
		Control		Irradiated	
Month	Storage Temperature	Percentage	Length	Percentage	Length
November	60°F	10	Visible only	nil	nil
December	60	90	3/4" to 1-1/2"	"	"
January	60	100	3" to 6"	"	"
February	58	100	6" to 8"	"	"
March	58	100	10" to 24"	"	"
April	70	Total loss		"	"
May	70	"	"	"	"
June	80	"	"	"	"

From February onward all control tubers were soft. In March control tubers had shown considerable wilting and were shrivelled.

Participants in the program provided the potatoes and subsequently stored them alongside untreated controls under identical conditions. The potatoes remained the property of participants who were at liberty to sell them (after allowing for a sufficient time of observation) in whatever

market in Canada appeared most advantageous.

(d) Local inspectors of the Fruit and Vegetable Division of the Canadian Department of Agriculture assisted at the time of irradiation and at intervals thereafter. Some participants performed detailed tests on content of reducing sugars, starch, and ascorbic acid. The results observed were satisfactory.

4. (a) (i) A dose of 8,000 rads ±13% was completely effective in controlling sprouts in all 26 storage locations regardless of variety, storage temperature, date of irradiation. method of storage, or length of storage.

(ii) A few lots displayed short sprouts at time of treatment. Further sprouting was stopped and growth of existing sprouts was arrested.

(iii) Radiation was observed to be a more potent sprout inhibitor than other methods used in the same storages. This comparison was possible at a number of locations.

(iv) Results indicate that even a lower dose would provide good commercial control of sprouting in at least a number of applications.

(v) No internal sprouting was observed in irradiated tubers. Some was found in controls. Storage quality was, in general, comparable with original quality of the potatoes. Irradiated potatoes remained firmer than the controls which became soft and spongy as sprouting progressed.

(vi) A few trials exhibited poor storage quality. All of these occurred in one locality which may be a reflection of the general harvest and storage conditions. In that locality the growing season was extremely wet with the result that spraying for blight was not carried out properly.

(vii) The most common defect found in both control and irradiated potatoes was dry rot which developed from mechanical or other injury. This indicates the need for careful handling during processing. These two problems will be further investigated in trials during the fall of 1962 and winter of 1963. Processing on a full scale basis would simplify handling since it would not be necessary to use such small buckets. It is anticipated that this will correct the problem of dry rot.

(viii) Carefully handled potatoes treated promptly following digging, and without curing, stored particularly well.

(ix) Observations made in a retail market and in a separate experiment showed that irradiated potatoes are more resistant to light greening than unirradiated tubers.

(x) Irradiated potatoes were successfully processed into chips, instant mashed flakes, frozen french fries, and fresh boilers. The irradiation did not affect the quality.

(xi) Reducing sugar level differences among varieties were found to be more significant than between control and irradiated tubers of the same variety.

(xii) No complaints of any kind were received or reported regarding consumer acceptability of irradiated potatoes. Legislation in Canada does not require that the potatoes be labelled "irradiated" nor does it require that potatoes treated with other sprout inhibitors be so labelled.

(b) The program provided a good deal of new information for us and for the other participants. I am sure that it placed the possibilities in much better focus for the potato growers and processors. The results have created a favourable climate for commercial potato irradiation. Our program, related to Canadian conditions, has:

(i) Confirmed the desirability of pilot plant tests;

(ii) Provided the industry with an opportunity to evaluate the process in terms of their own conditions;

(iii) Ascertained consumer acceptability;

(iv) Assisted in educating industry and the public by the cooperative nature of the work.

5. (a) In view of the very favourable results on experimental and pilot run quantities, the matter of commercialization of the program is now reduced to its simplest terms - economics. Good economy can only be achieved by volume processing in a well designed and efficiently operated, full size irradiator.

(b) Although some standardization of design will be essential, we anticipate that different countries and different localities within the same country will require different machines for full scale quantity processing. Some variations in machine design will also be required, depending upon the type of storage and handling facilities available to the processor and upon the volume of product which can conveniently be processed in one location.

(c) Simplicity should be possible in all design variations thus making professional help unnecessary. This will be important particularly in areas where skilled technical operators are scarce.

(d) (i) The machine we envisage as suitable for most Canadian conditions would have a capacity of 100 to 200 megarad pounds per hour, representing a throughput of some 13,300 to 26,600 pounds of potatoes per hour. A source of between 60,000 and 120,000 curies of cobalt-60 would be required.

(ii) The machine would not be mobile and hence could make use of ordinary concrete or other cheap material for shielding.

(iii) The machines which we shall provide will make use of proven engineering techniques and standard components where possible. Design will be such that maintenance will be straightforward and infrequent. It is anticipated that only a semi-skilled technician will be required to operate a full scale machine.

(e) The source would be in the form of a plaque about 4' wide and somewhere between 4' and 8' long. A safe storage position is provided in a dry pit. To recharge the source, the pit would be filled with water.

(f) Produce treated would be in boxes 4' x 2' x 1'3" deep, or perhaps 4' x 4' x 1'3" deep, if more convenient to local storage. The box would enter and leave the irradiation chamber via mazes. The use of boxes is preferred because they provide uniformity, reduce damage to produce, enable a machine to be used for a variety of produce, and present some simplicity in the conveyor and handling systems.

(g) For lower throughputs - 20 to 30 megarad pounds per hour - even simpler preliminary designs are available.

(h) Based on measurements made on a model of a full size unit, radiation utilization efficiency is expected to be between 15 and 25% depending on special design features and throughput required.

(i) Machines for use in areas where labour is plentiful and relatively inexpensive will likely require fewer automatic features for loading and unloading of produce boxes.

6. (a) An exact estimate of processing costs cannot be made on a general basis. Costs per 100 pounds of produce throughput will depend on construction and labour cost in the area; throughput - whether the machine can be used for other products in the off season; the type of storage and handling facilities already available or to be provided; and on other considerations.

(b) Nevertheless, if we assume conditions as we know them in Canada, we estimate that a full scale radiation processing facility for potato sprout inhibition can be provided at prices which will permit total processing costs of about 15¢ per 100 pounds. This can be reduced proportionately if commercial scale processing can tolerate a dose of less than 8,000 rads.

(i) The estimate is based on a throughput of about 50 million pounds per season. A throughput of 25 million pounds per season would probably cost about 24¢ per 100 pounds. If the machine is located where reasonable quantities of, say, carrots and onions can also be processed, worthwhile savings will be realized because of the increase in the operating period during the season.

(ii) These cost estimates are based on today's commercial prices for cobalt-60 and for construction of equipment. They include provision for complete write-off of the facility in 10 years plus

interest at 6% per annum on the unpaid balance of original cost. Also included is provision for annual replenishment of the source, operating labour at $9.00 per hour, and overhead at 100% of labour.

(c) Estimates for carrots and onions to prevent sprouting are respectively a little more, and a little less, than for potatoes at similar throughputs.

(d) It appears that for seasonal operation of potato processing plants, substantial savings can be made compared with otherwise necessary importation of potatoes when prices are high.

7. (a) I mentioned earlier that the conditions which obtain in Canada are probably different from those in many other areas. This could be an advantage or a disadvantage.

(b) It seems to us that in the investigation of the treatment of food products by irradiation, in most instances field trials are important as well as laboratory tests. These can be carried out in cooperation with government and industry. Early experiments can be made using laboratory equipment capable of processing a few pounds at a time. Field tests can be done very well on a mobile unit of the type which we used. It is not recommended that pilot plant quantities be shipped to a stationary unit for testing a process. This introduces additional handling and other changes in conditions which may be significant.

(c) Cobalt irradiation facilities can be operated without any large requirements for outside power. The simplicity of design and operation permits the use of technicians rather than scientists or engineers and provides for low operating cost. This should be particularly attractive in areas where skilled personnel are scarce.

(d) The reduction of spoilage in food products will have a significance (for other than purely economic reasons) even greater in areas of high population density and low per capita production of food.

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